Annual meeting, Human Factors Society
Palo Alto, California
Oct. 23-25, 1963 X64 10373

13p

code 2A
(NASA CR-52628)

LANGLEY RESEARCH CENTER SIMULATORS

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[1963] 13p (OTS)

The NASA Langley Research Center is the oldest of the NASA research facilities, being established as a function of the National Advisory Committee on Aeronautics in 1917 for the purpose of carrying out flight research. We are not sure as to the exact definition of flight research but may note that papers on handling qualities began appearing soon after the founding of the Laboratory at Langley Field, Virginia. Since most flight systems are man-machine systems, it is not surprising to find that the man-machine integration problem soon became the object of considerable research.

Since October 1, 1958, the NASA, the successor to the NACA, has been formally charged with the investigation of manned spaceflight along with a continuing responsibility for the investigation of aeronautical flight. The Langley Research Center has since been active in support of Projects Mercury, Gemini, and Apollo, theoretical investigation of manned spaceflight systems and in the continuing investigation of the problems of aeronautical flight systems.

The nature of the simulation program which has arisen in connection with these efforts may be taken as an implicit summary of the Langley Research Center philosophy concerning manned flight systems.

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~~To be~~ Presented at the 1963 Annu~~al~~ Meeting of the Human Factors Soc~~iety~~, October 23, at San Francisco, California.

San Francisco, Oct. 23

In a manned system, man is considered to be a major component of the flight system and it is therefore necessary to investigate the contributions which he may be expected to make as well as the limits which he may impose on the system.

Man's contribution may be best measured in the context of an experimental procedure which provides for as many of the actual flight conditions as possible. Where such an experimental procedure involves a simulator, the technology is necessarily complex. In view of the complexity of the major simulation efforts at the Center, it is necessary to confine the scope of this presentation to the major simulator systems and the areas in which they are being used to the exclusion of the numerous smaller research programs which use part-task simulation or specific experimental situations designed perhaps for a specific segment of the problem.

While a major emphasis is placed on the simulators as a means to an end while the program is bounded by the realization that the problems of manned flight are real and compelling, simulator technology is in itself an item of interest and of some research.

The missions are adequately described in the literature and will not be specifically discussed. Simulator technology, while of interest, is not the primary focus of this meeting. It is proper, however, to present the simulators as tools which have evolved or which have been designed to aid in the investigation of specific problem areas. In this context some thought may be given to the problems before proceeding to a consideration of the research equipment.

Space flight systems are basically undamped inertial systems. Since they are marginally controllable in three axes of attitude, for example, automatic stability augmentation systems are attractive but of necessity fallible. Controls, displays and pilot techniques are required for manual control in the event of failure of the augmentation system. Vertical descent in an airless environment utilizing either fixed or variable thrust vectors poses a difficult problem. Rendezvous-docking of inertial systems by manual control requires simultaneous control of six degrees of freedom. Control inputs are ordinarily in terms of a force applied to a moment arm or along a velocity vector. Such forces require accurate application.

There are many unusual visual problems such as the requirement for accurate judgment of distance and small rates of angular motion in an environment where a frame of reference may be absent or where visibility may be quite low. Lighting conditions within the spacecraft may not necessarily be compatible with requirements for extra-vehicular visual perception.

Man's effectiveness as a controller is affected by his reaction to varying gravity fields. He may be subject to fields varying from zero to near tolerance limits. The problem is further confounded by the fact that rotation, often suggested as a means of providing artificial gravity during orbit, may produce as many disrupting psychological affects as it overcomes.

New display and control concepts are constantly generated. Some of these techniques have promise and must be evaluated. If acceptable, their integration into a total display concept or display-control system must be tested.

Crew workloads and management of complex mixes of continous control and information processing is an important area of manned flight. Time, fuel, and velocity are often rigid constraints on the pilot or astronaut. Landing a supersonic commercial transport at a major airport will require the concerted efforts of tens and perhaps hundreds of persons if safe, efficient commercial flight is to become a reality.

The Langley Research Center Simulation Program is oriented toward the mission as a sequence of events which may present some or all of these constraints. Therefore, while much of the research now in progress is of general or theoretical interest, it is closely related to the programed NASA missions.

Both space and air transport missions are adequately described in the literature ( ) and will not be specifically presented nor discussed in detail. The major purpose of this discussion is to discuss the technological features of the Langley Research Center manned-flight simulators.

PLANETARIUM

There is now in existence a 57-foot planetarium which is shown in Figure 1. This system is a Dewline radome, an inflatable sphere

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SLIDE 1

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57-foot in diameter, truncated so that the center of the sphere is

9 feet above the floor of the hangar. It has a combination light and air lock and provides a dark-field environment.

A star projector with individual lenses for each star above the fifth magnitude is under construction. The star projector will be based on a Nike-Ajax radar antenna mount which has a tracking accuracy of degrees under field conditions.

The star drive is designed to be operated by an adjacent 631-R analog computer which has some amplifiers with an adequate number of percision electronic multipliers, diode function generators and precision servo-resolvers. In addition, tielines to the Center's major computer facility are being installed. A Trice computer, a 7094 and several 1620 computers are available for digital programs, while a 700 amplifier 631-R complex is available for more elaborate analog computations than the small analog machine will provide.

In addition, a three-axis grimbal rig which will support a large cockpit is available. This system has hydraulic servomotors which can be driven from the 631-R computers. Smaller fixed base cockpits are also available.

It can be seen that a large spherical dark room supported by analog computing equipment can be used for a wide variety of dark-field studies. These include rendezvous with a vehicle equipped with flashing lights, planetary navigation experiments, the testing of various schemes for human optic location and ranging and other studies.

For convenience, illustrative studies are listed in the bibliography (   ).

As a general summary of the capacity of this simulator, investigation of various dark-field phenomena are based on the assumption that if the pilot can acquire, track and rendezvous with passive targets by means of his visual perception and manual control capability, the manned backup of automated systems designed for this mission phase will greatly enhance the probability of mission success. The use of this simulator is predicated on the assumption that man can make a positive contribution to this area of spaceflight, and since research has confirmed this assumption, considerable research on problems such as probability of acquisition of an identifying light, ability of the pilot to judge small rates against a star background,ability to null rates relative to his spacecraft and to participate in the navigation procedure by various means will be continuous.

In addition to this dark-field simulation, it should be mentioned that the Langley Research Center has a 3,000-foot hydrodynamic tow tank which can be darkened to provide perhaps the world's longest dark room for studies involving distance judgment. While this facility was not planned primarily to support spaceflight research, it is being used in such a context.

GEMINI VISUAL DOCKING SIMULATOR

While many of the important aspects of pilot controlled rendezvous can be investigated in the planetarium, it is not particularly well suited to dimensions less that perhaps 2,000 feet. A fixed-base

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Figure 2
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simulator designed to cover the docking situation, essentially the last 1,000 feet, is shown in Figure 2. A small scale model of the target vehicle, controlled by an analog computer, is mounted so that it rotates in three degrees of freedom and translated along the camera axis. The image is then transmitted via the TV camera to a two-axis mirror mounted above the pilot's head at the center of a 20-foot-diameter sphere. The full six degrees of freedom of motion of the capsule relative to the target vehicle is then available.

This simulation is initiated with 1,000 feet of the target vehicle with various initial conditions of motion of the Gemini spacecraft and continued to within the range of theoretical contact. It can therefore be used to study effect of control modes, thrust levels, systems failures, lighting conditions and crew workloads on the ability of the pilots to perform the Gemini docking operation.

Should the conversion be desirable, other systems can be simulated by changing the capsule display system, simulated windows and vehicle dynamics. It is anticipated, however, that the research will continue on the Gemini configuration for some time to come.

DOCKING FACILITY

A dynamic simulation of rendezvous operations is apt to an expensive and nontrivial simulation, since ranges of 50 miles would be involved. We are not surprised to find that the major part of the rendezvous simulation is done by fixed base equipment. The docking phase, however, is quite different, being defined roughly as the final approach with some hundreds of feet. If we wish to limit this to some several-hundred feet, we find that a dynamic simulation is feasible.

Such a system is now in operation at the Langley Research Center and is shown in Slide 3. In essence this is a servo-controlled

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SLIDE 3
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overhead traveling bridge crane designed by the Langley Research Center. The overhead crane carriage moves 210 feet along the flight path, and 12 feet across the flight path. A cable drive moves a payload some 46 feet in the vertical direction.

All three degrees of translational freedom are provided by servomotors driven from a 631-R analog computer. The payload is a three-axis grimbal system from which various cockpit assemblies can be driven. A full scale Gemini capsule is presently mounted for use in study of docking the Gemini with an Agena target.

In this program pilot techniques, the effects of system failures and the effectiveness of various control modes are being studied, along with other variables such as lighting angles, etc.

We note also that there is a striking similarity between the fixed base and dynamic Gemini simulation, a situation which provides for a test of the overall effectiveness of static versus dynamic simulation of a well defined mission phase with a well defined vehicle or flight system. An investigation of these two systems in terms of pilot techniques, errors, fuel use and other pertinent parameters is now underway. It is becoming apparent that we must not only concern ourselves with the simulation of the task to be investigated but must devote a certain amount of our resources to an investigation of simulators themselves, so that it becomes somewhat difficult to separate out research with simulators from research on simulators.

LUNAR LETDOWN SIMULATOR

After the rendezvous and docking phases of space missions are studied, it becomes necessary to consider terminal phases. Earth-terminal or reentry phases of manned missions is not presently under intensive study at the Langley Research Center. This, to some extent, is due to the intensive study of this problem which accompanies present projects such as the Gemini and Apollo, where such studies are carried out by the project groups and contractors responsible for the execution of these projects. The lunar-terminal event poses problems which are only in part related to major design criteria.

Experience with reentry mechanics and procedures was gained during the Mercury flights and will be studied during the Gemini flights. All of this experience will be to some degree applicable to the Apollo flight, but at the time of the first lunar landing our experience with lunar terminal conditions will be exactly zero, a conclusion which dictates research of this problem by simulation.

One of the more important aspects of the mission in the neighborhood of the moon is the determination of the optimal division of duties between the man and the automatic system. The man-machine capability in this domain can be assessed by simulation, but simulation of the vehicle environment as well as the dynamics of the spacecraft is essential. The Lunar Letdown Simulator often called LOLA is being constructed to provide both a visual environment in the neighborhood of the moon and simulation of vehicle dynamics.

The simulator consists of a spacecraft, a closed circuit TV complex, computer driven cameras and models of the lunar surface. This is shown in Slide .

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SLIDE 4
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There are four models which permit altitude coverage of 200 feet - 200 miles above the lunar surface. The models include a 20-foot-diameter sphere and three spherical segments.

The TV cameras are arranged so that one camera transport mechanism can cover two segments and a sphere, while a second camera covers the remaining segment. Each camera complex consists of four cameras mounted so that each looks at a portion of the view analogous to that seen from four windows in an approaching spacecraft. These views will be projected for the pilot as though he were sitting in a spacecraft viewing these four windows.

The pilot will be given a set of initial conditions at 200 miles and will be required to establish an orbit, to determine the orbit characteristics, descend to 200 feet and hover over a predetermined landing site. He will use the lunar surface, horizon, landmarks, etc., to perform these tasks.

Since the final 200 feet is within the scope of a dynamic mechanization, we have designed and are constructing a Lunar Landing Research Facility. This facility is sketched in Slide Five.

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SLIDE 5
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This is an overhead crane structure about 250 feet high and 400 feet long. The crane system will support 5/6 the weight through servo-driven vertical cables so that the remaining 1/6 of the weight gives a downard component equal to lunar g.

This system is, for the pilot, open loop, although a servo system operates to keep the cables vertical at all times by moving the overhead crane carriage. The test vehicle, or "bug" has been delivered and is being tested and fitted out. It is a research vehicle, not a model of the Lunar Excursion Module and is quite flexible in terms of research applications. The crane is capable, however, of handling a vehicle weighing up to 20,000 pounds and of initial conditions of 50 fps horizontally and 30 fps vertically. A catapult provides the initial conditions.

It should be noted that this is an open loop system using real reaction systems. For example, the research vehicle has thrust levels of 600 - 6,000 pounds available to the main engines, attitude reaction control jets and will hence provide a realistic simulation of the letdown of a large flight system using reaction systems. The application to the lunar landing mission is, obviously, to test man's ability to hover and to land such systems under various conditions.

The design is such that other studies can also be carried out. These might be large scale rendezvous-docking, space assembly of large objects, construction of a moon base in terms of materials handling, righting capsized spacecraft, etc.

This completes the picture of the large scale manned-space simulators designed and constructed for the purpose of assessing man's contributions to spaceflight systems. As I have indicated, the excitement of participation in the space program sometimes obscures the continuing developments in aeronautical flight systems.

As you may know, there is a strong national interest in the supersonic commercial air transport. Much basic research on configurations and feasibility is underway at the Langley Research Center. As this research progresses, it becomes obvious that landing and take-off from airports adequate even for our largest subsonic jet planes will pose some problems. The SCT must of necessity be quite large and designed primarily for high-altitude high-Mach flight but landing and take-off requirements dictate a reasonable speed over the fence. The second problem is that loiter time in the vicinity of the airport is quite short. In fact, it is practically nonexistent.

In addition, traffic forecast for the operating period of the SCT indicates that the present airway congestion will not get any better. The problem is therefore two-fold.

Landings and take-off will be exacting and a clear traffic pattern is advisable. The Aeromechanics and Technology Division has undertaken to simulate, then, complete mission operation of such a plane in conjunction with the FAA air traffic control research facility at Atlantic City so that the simulation will provide the research pilot with a simulation of the machine dynamics, traffic patterns and crew workloads during the critical phases of take-off, entering and clearing local traffic, transition to transonic speeds and the inverse operation of converting to a subsonic configuration, clearing traffic and landing.

SUMMARY

It can be seen that most of these simulations are similar in that they involve relatively large and realistic simulation of complex event sequences, that they rest on a foundation of engineering precision and integrated computer support and that they are designed to evaluate man's contribution to the flight system in the largest possible frame of reference. They are not designed to show that man is superior to the machine, nor to show that man limits the performance of a flight system, but to aid in the rational study of optimal combinations of human and machine characteristics so that the mission at hand may be carried out effectively and safely.